

TITLE OF THE INVENTION

TURBO CHARGER FOR INTERNAL-COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

(Field of the Invention)

[0001] The present invention relates to a turbocharger for an internal combustion engine and, more particularly, to a bearing of a rotary shaft obtained by integrating a turbine blade and a compressor blade.

(Prior Art)

[0002] Generally, a turbocharger for an internal combustion engine is driven by energy of exhaust gas. In the turbocharger, a turbine housing and a compressor housing are disposed so as to sandwich a bearing housing of a rotary shaft (drive shaft).

[0003] A turbine blade which receives pressure and temperature energy of exhaust gas of an internal combustion engine and rotates is attached to one end of the rotary shaft, and a compressor blade which is rotated by the power of the turbine blade and compresses air by the centrifugal force of rotation to generate boost pressure is attached to the other end of the rotary shaft.

[0004] As a radial bearing of the rotary shaft of an exhaust gas turbine (rotary shaft of the turbocharger), one which is resistant to high-speed rotation and shaft vibration is used. As an optimum radial bearing, a floating metal (floating bearing) is used.

[0005] In the radial bearing (floating metal), a proper clearance is set between the inner side of the bearing and the outer side of the rotary shaft and between the outer side of the bearing and the inner side of the bearing housing. Engine oil is applied to the clearance and the rotary shaft is supported in a floating state by an oil film of the engine oil.

[0006] The radial bearings are disclosed in Japanese application patent laid-open publication Nos. Hei 6-42361 and Hei 11-36878.

[0007] As disclosed in the publications, a thrust bearing for the turbocharger is often in contact with an end face of the bearing housing on the compressor side relatively apart from the turbine side.

[0008] Concretely, by connecting a pipe branched from a lubricant oil path of the body of an internal combustion engine to the bearing housing of the turbocharger for an internal combustion engine, the engine oil is supplied in a manner similar to the bearings of the internal combustion engine.

[0009] The engine oil supplied to the bearing housing is force fed into an annular gap formed along the inner side of the radial bearing, an annular gap formed along the outer side, and gaps formed on the right and left side faces of the thrust bearing via oil paths and an optimum oil film is formed in each of the gaps. With the configuration, a damping action for suppressing shaft vibration which occurs when the rotary shaft rotates at high speed is displayed, and the stable state of the rotary shaft which rotates at 100,000 rpm/min is maintained.

[0010] There are a type of using two radial bearings for a turbocharger and a type of using only one radial bearing. In the former type, the radial bearings are disposed on the turbine blade side and the compressor blade side of the rotary shaft. In the latter type, the radial bearing in a sleeve shape which is relatively long in the axial direction is disposed in the center portion of the rotary shaft. There are also two types; a type in which rotation of the radial bearing itself is regulated, and a type in which the radial bearing itself is also rotated in association with the rotation of the rotary shaft.

## SUMMARY OF THE INVENTION

### (Problems to be Solved by the Invention)

[0011] For both of the radial and thrust bearings of a turbocharger for an internal combustion engine of recent years, a copper alloy material is used. A lead bronze casting typified by CAC603, a sintered material corresponding to the above, and a brass alloy containing about 70% of Cu are in the mainstream.

[0012] It is known that, when oil cooling is not considered, the temperature of the engine oil becomes very high, and the bearings are attached by an S component in the engine oil in a high-temperature environment, corroded, and turn black. A black corrosion product generated on the surface of a bearing is easily peeled by abrasion, and it causes abnormal abrasion in the bearing.

[0013] Particularly, the turbocharger (of an exhaust gas turbine type) uses heat energy of exhaust gas, so that the temperature becomes high. In an atmosphere in a high-temperature engine room immediately after high-speed and high-load driving of an internal combustion engine, the temperature increases to about 250°C in the radial bearing on the turbine side and to about 180°C in the thrust bearing, so that a high temperature environment in which the black corrosion product is created is obtained.

[0014] To suppress the black corrosion product generated in the copper alloy materials, it is effective to use a brass alloy material containing about 60% of Cu.

[0015] A general brass alloy material has excellent machinability. On the other hand, the machinability severely deteriorates the abrasion resistance. In the case of using the material for the bearing for the turbocharger, there is a problem such that abnormal abrasion occurs in relatively short time due to disturbances such as shaft vibration of the high-speed rotary shaft and metal contamination floating in the engine oil. Under present circumstances, it is difficult to use the material.

[0016] An object of the invention is to provide an exhaust turbocharger having excellent durability by a bearing structure with excellent abrasion resistance without generating a black corrosion product even in a high-temperature oil environment.

(Means for Solving the Problems)

**[0017]** According to the invention, to achieve the object, basically, in a turbocharger for an internal combustion engine, a radial bearing for supporting a rotary shaft of the turbocharger is made of a copper alloy containing, as main components, Cu, Zn, Al, Mn, and Si.

**[0018]** In the configuration, by maintaining basic alloy components of a general brass containing Cu and Zn as main components (60% of Cu and 40% of Zn), a black corrosion product which is generated in the high-temperature engine oil environment can be suppressed. Moreover, by adding Al, Mn, and Si, the hardness of the alloy is increased, and abrasion resistance of the rotary shaft of the turbocharger which rotates at high speed can be also improved.

**[0019]** For example, a turbocharger according to the invention is provided with a radial bearing made of a brass copper alloy containing 54 to 64 wt% of Cu, 0.2 to 3.0 wt% of Si, 0.2 to 7.0 wt% of Mn, 0.5 to 3.5 wt% of Al, and the rest of substantially Zn.

**[0020]** In the configuration, in a radial bearing for supporting a rotary shaft of the turbocharger, an Mn-Si compound is crystallized as a hard phase in a brass base material. The crystallized compound is an element which improves the abrasion resistance of the rotary shaft.

[0021] In order to display abrasion resistance more effectively, the Mn-Si compound is dispersed so as to be elongated in the axial direction of the radial bearing (the details will be described in the embodiments).

[0022] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a cross section showing the structure of a turbocharger for an internal combustion engine according to an embodiment of the invention.

[0024] FIG. 2 is a partly enlarged cross section showing an attaching structure of a radial bearing 10 on a turbine side of the turbocharger illustrated in FIG. 1.

[0025] FIG. 3 is a cross section showing an attaching structure of the radial bearing 10 and a thrust bearing 11 on a compressor side of the turbocharger illustrated in FIG. 1.

[0026] FIG. 4 is a microscope observation diagram showing a cross-sectional structure in the radial direction and a cross sectional structure in the axial direction of an Mn-Si compound crystallized out on a bearing member of the invention.

[0027] FIG. 5 is a diagram showing examples of composition of a bearing member for a turbocharger according to the embodiment of the invention and compositions of comparative examples.

[0028] FIG. 6 is an explanatory diagram showing the relation between the sliding direction with respect to the Mn-Si compound crystallized out on the bearing member and an abrasion amount.

[0029] FIG. 7 is an explanatory diagram showing evaluation on protection against corrosion of the bearing members for the turbocharger according to the embodiment of the invention and those of the comparative examples.

[0030] FIG. 8 is an explanatory diagram showing evaluation on abrasion resistance of the bearing members for the turbocharger according to the embodiment of the invention and those of the comparative examples.

[0031] FIG. 9 is an external view photograph showing a material A which are new (radial bearings for a conventional turbocharger) shown in FIG. 5 before immersion in high-temperature oil.

[0032] FIG. 10 is an external view photograph showing a state of the material A after immersion in oil of 180°C for 48 hours.

[0033] FIG. 11 is an external view photograph showing a material B which is new (thrust bearings for the conventional turbocharger) shown in FIG. 5 before immersion in high-temperature oil.

[0034] FIG. 12 is an external view photograph showing a state of the material B after immersion in oil of 180°C for 48 hours.

[0035] FIG. 13 is an external view photograph showing a material C which is new shown in FIG. 5 before immersion in high-temperature oil.

[0036] FIG. 14 is an external view photograph showing a state of the material C after immersion in oil of 180°C for 48 hours.

[0037] FIG. 15 is an external view photograph showing a material D which is new shown in FIG. 5 before immersion in high-temperature oil.

[0038] FIG. 16 is an external view photograph showing a state of the material D after immersion in oil of 180°C for 48 hours.

[0039] FIG. 17 is an external view photograph showing a material E which is new (radial bearings for the turbocharger according to the invention) shown in FIG. 5 before immersion in high-temperature oil.

[0040] FIG. 18 is an external view photograph showing a state of the material E after immersion in oil of 250°C for 48 hours.

[0041] FIG. 19 is an external view photograph showing a material F (radial bearings for the turbocharger according to the invention) shown in FIG. 5 after immersion in oil of 250°C for 48 hours.



## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0042] Embodiments of the invention will be described hereinbelow with reference to the drawings.

[0043] FIG. 1 is a cross section showing the structure of a turbocharger for an internal combustion engine according an embodiment of the invention.

[0044] The charger body is constructed by a bearing housing 12, a turbine housing 2, and a compressor housing 8. The turbine housing 2 and compressor housing 8 are disposed on both sides of the bearing housing 12.

[0045] A rotary shaft 3 is supported by two radial bearings 10 and one thrust bearing 11 disposed in the bearing housing 12. A turbine blade 1 is attached to one end of the rotary shaft 3, and a compressor blade 5 is attached to the other end.

[0046] As each of the radial bearings 10 for supporting rotation in the radial direction of the rotary shaft 10, which is resistant to high-speed rotation and shaft vibration, a floating metal using engine oil is used. On the right and left side faces of the thrust bearing 11, the engine oil is also introduced and an oil film is formed. The structure and material of the bearings 10 will be described hereinlater.

[0047] Exhaust gas exhausted from each of cylinders of the internal combustion engine is collected by an exhaust pipe (not shown) disposed on the internal combustion engine side and introduced to the turbine housing 2. The

turbine blade 1 and the rotary shaft 3 are integrally joined and positioned in the center portion of the turbine housing 2. The compressor blade 5 is integrally fastened to the rotary shaft 3 by engagement of a male screw formed at an end of the rotary shaft 3 and a lock nut 6. The turbine blade 1 and the rotary shaft 3 are integrated by, for example, friction welding.

**[0048]** The thrust bearing 11 for regulating movement in the thrust direction of the rotary shaft 3 is provided at one end of the bearing housing 12 near to the compressor.

**[0049]** A collar (thrust collar) 4 adapted to the thrust shaft fit in the thrust bearing 11 is inserted together with the compressor blade 5 to the rotary shaft 3 and fixed to the rotary shaft 3 by fastening of the lock nut 6.

**[0050]** When the turbine blade 1 rotates at high speed by the pressure and temperature energy of the exhaust gas introduced into the turbine housing 2, the rotary shaft 3, thrust collar 4, and compressor blade 5 integrated with the turbine blade 1 similarly rotate at high speed.

**[0051]** A scroll path 9 of the compressor is constructed by a housing 8 and a scroll sheet 7. By the rotation of the compressor blade 5, compressed air is generated in the scroll path 9 and force-fed into an intake path of the internal combustion engine.

**[0052]** The configuration of the radial bearing 10 and thrust bearing 11 will now be described.

[0053] The radial bearings 10 of the embodiment are of a full-float type and disposed in positions near to both ends of the bearing housing 12.

[0054] In the bearing housing 12, a path 13 for introducing the engine oil, an oil path 13c communicated with the path 13, and paths 13a and 13b branched from the oil path 13c are formed. The engine oil of the internal combustion engine is supplied to the radial bearings 10 and thrust bearing 11 via the paths.

[0055] Figs. 2 and 3 are enlarged views of a portion around the radial bearings 10 and thrust bearing 11.

[0056] FIG. 2 is a cross section showing an attaching structure of the radial bearing 10 on the turbine side, and FIG. 3 is a cross section showing an attaching structure of the radial bearings 10 and thrust bearing 11 on the compressor side.

[0057] As shown in FIG. 2, two annular grooves 12b are formed in an inner portion 12a (inner circumference of a hole through which the rotary shaft is passed) of the bearing housing 12, and two stopper rings 14 for regulating movement in the axial direction of the radial bearings 10 are inserted and fixed in the grooves 12b. The radial bearing 10 on the turbine side is provided between the stopper rings 14. On the other hand, the radial bearing 10 on the compressor side is disposed between a stopper ring 14' inserted and fixed in the inner circumference of the bearing and the thrust collar 4.

[0058] The radial bearings 10 are full floating metals whose inner and outer circumferences are supported by oil films. Therefore, a plurality of oil passing holes (orifices) 10a penetrating the ring-shaped metal are provided at equal intervals in the circumferential direction. Between the inner portion 12a of the bearing housing 12 and the outer portion of the radial bearing 10 and between the inner portion of the radial bearing 10 and the outer portion of the rotary shaft 3, a proper clearance is set.

[0059] Engine oil is force fed via the oil path 13a to the outer portion (clearance) of the radial bearing 10 on the turbine side, and is also supplied to the inner portion (clearance) of the radial bearing 10 via the orifices 10a formed in the bearing 10. Similarly, the engine oil is supplied to the outer and inner portions of the radial bearing 10 on the compressor side via the orifices 10a formed in the oil path 13b and the bearing.

[0060] Therefore, in each of the proper clearance between the inner portion 12a of the bearing housing 12 and the outer portion of the radial bearing 10 and in the proper clearance between the inner portion of the radial bearing 10 and the outer circumferential portion of the rotary shaft 3, a required oil film is assured, so that the action of damping the high-speed driving of the rotary shaft 3 and the like can be sufficiently displayed, and stable high-speed rotating operation can be maintained.

[0061] For the thrust bearing portion shown in FIG. 3 as well, the engine oil is supplied in a manner similar to the radial bearings 10.

[0062] Generally, in the thrust bearing 11 fixed to an end face of the bearing housing 12 by a screw or the like, an oil feeding path 11a and oil feeding holes 11b and 11c are formed. The oil feeding path 11a is communicated with the oil path 13c in the bearing housing 12. In a manner similar to the radial bearing 10, the engine oil is supplied to the oil feeding path 11a.

[0063] The engine oil supplied to the oil feeding path 11a is force fed to the proper clearance assured on both side faces 11d and 11e of the thrust bearing 11 via the oil supplying holes 11b and 11c and is also force fed to the proper clearance assured between the thrust bearing and flanges 4a and 4b of the thrust collar 4.

[0064] With the configuration, an oil film having a required thickness is assured in each of the clearances to support high-speed rotation of the rotary shaft 3 and the damping action in the thrust direction for sudden acceleration/deceleration driving and the like are sufficiently displayed. Thus, stable high-speed rotational motion is maintained.

[0065] In the above structure, a driving mode in which the bearing portion is in the severest environment from the viewpoint of temperature will be described.

[0066] During operation of the internal combustion engine, the engine oil branched from the lubricating oil path of the internal combustion engine is

supplied to each of the bearings. Consequently, in the temperature environment of the radial bearings 10 and thrust bearing 11, the temperature of the engine oil is dominant. The temperature is around 100°C at the time of driving in a general city and is about 150°C at the time of high-speed driving and continuous driving on a hill.

[0067] However, in a stop mode after high-speed driving and continuous driving on a hill, due to heat radiation and heat transmission from the turbine housing 2 in which heat is accumulated by the exhaust gas during driving, a heat soak back phenomenon that the temperature environment becomes equal to or higher than the temperature during driving after the internal combustion engine stops occurs. The temperature in the radial bearing 10 on the turbine side becomes around 250°C and the temperature in the thrust bearing 11 increases around 180°C.

[0068] Even in the state where the internal combustion engine is stopped, the engine oil remains in the proper clearances set in the inner and outer portions of the radial bearings 10 and both end faces of the thrust bearing 11. In the case where the radial bearings 10 and the thrust bearing 11 are made of conventional materials, if any of countermeasure (for example, cooling means) is not taken in the high-temperature environment when the heat soak back phenomenon occurs, the bearings are attacked by the high-temperature engine oil, and a black corrosion product is created relatively easily.

[0069] In the embodiment, a turbocharger having bearings achieving sufficient protection against corrosion and abrasion resistance even in the high-temperature engine oil environment is provided. After trial and error, the inventors herein have found that a bearing of a turbocharger sufficiently resistant in the high-temperature engine oil environment is achieved by making the radial bearings of a copper alloy whose main components are Cu, Zn, Al, Mn, and Si, so that the radial bearing is made of such a copper alloy.

[0070] Various materials of the bearings of a turbocharger of this kind were examined, and evaluation on results of protection-against-corrosion tests in an engine oil of high temperatures (180°C and 250°C) of the materials will be described.

[0071] FIG. 5 shows materials used in this case.

[0072] Materials A and B in FIG. 5 are generally employed for a bearing for a turbocharger according to a conventional technique. A material A is a brass alloy (containing 70 wt% of Cu, 6.52 wt% of Pb, 0.1 wt% of Fe, and the rest of Zn), and a material B is lead bronze (containing 78.2 wt% of Cu, 10.5 wt% of Pb, 0.11 wt% of Fe, 0.83 wt% of Zn, and the rest of Sn). Materials C and D are specimens (general brass material containing about 60 % of Cu) each examined as the material of a bearing but is not employed due to inferior abrasion resistance. The materials C and D are brass alloys each having the effect of preventing occurrence of a black corrosion product. The material C contains 60.8

wt% of Cu, 0.1 wt% or less of Pb, 0.1 wt% or less of Fe, and the rest of Zn. The material D contains 60.2 wt% of Cu, 1.30 wt% of Pb, 0.1 wt% or less of Fe, and the rest of Zn.

**[0073]** Materials E and F are materials of the invention intended to prevent occurrence of a black corrosion product and improve abrasion resistance. The material E is a brass alloy containing 62.1 wt% of Cu, 3.05 wt% of Al, 3.16 wt% of Mn, 0.92 wt% of Si, 0.2 wt% or less of Pb, and the rest of Zn. Such a brass alloy itself is known as YZ6 (manufactured by Daido Metal) but is an unknown material as the material of a bearing in a conventional turbocharger. The material F is a brass alloy containing 58.3 wt% of Cu, 0.69 wt% of Al, 3.72 wt% of Mn, 1.46 wt% of Si, and the rest of Zn. Such a brass alloy itself is known as SAM214 (manufactured by Hitachi, Ltd.) but is an unknown material as the material of a bearing of a conventional turbocharger.

**[0074]** To the bearing for a turbocharger made of the material E as the embodiment of the invention, a small amount of Pb ( $\leq 0.2\%$ ) is added to improve machinability. Also by adding an element for improving machinability considering resistance to severe environment of Bi or the like, a similar effect can be obtained.

**[0075]** Figs. 9 to 19 are external view photographs showing evaluation tests conducted on samples before being immersed in high-temperature oil (new items) and after immersed for predetermined time.



[0076] FIG. 9 is an external view photograph which is a plan view of the new radial bearings 10 made of the material A before immersed in high-temperature oil. Two samples are provided. A scale is shown in the lower part of the photograph. In the radial bearings 10 in FIG. 9, although there are portions seen black due to shading of gloss, in reality, the whole bearings are shining with a gloss peculiar to a brass alloy.

[0077] FIG. 10 is an external view photograph showing the radial bearings (made of the material A) of FIG. 9 after immersed in oil of 180°C for 48 hours. In the case of the samples, after immersion in the oil of 180°C for 48 hours, a black corrosion product is generated on the whole face, and surface peeling occurs locally.

[0078] FIG. 11 is an external view photograph which is a plan view of the new thrust bearings 11 in FIG. 1 made of the material B before immersed in high-temperature oil. Two samples are provided. Although the thrust bearings 11 in FIG. 11 are partly seen black due to shading of gloss, in reality, the whole bearings are shining with a gloss peculiar to a bronze alloy.

[0079] FIG. 12 is an external view photograph showing the thrust bearings (made of the material B) of FIG. 11 after immersion in oil of 180°C for 48 hours. In the case of the samples as well, in a manner similar to FIG. 10, after immersion in the oil of 180°C for 48 hours, a black corrosion product is generated on the whole faces. Also, surface peeling occurs locally.

[0080] FIG. 13 is an external view photograph which is a plan view of a new material block made of the material C as a candidate of the material of the bearing for a turbocharger before immersion in high-temperature oil. Although the material block is partly seen black due to shading of gloss, in reality, the whole is shining with a gloss peculiar to a brass alloy. FIG. 14 is an external view photograph showing a material block made of the material C after immersion in oil of 180°C for 48 hours. In this case, a black corrosion product is not generated in evaluation after the immersion, and largely improved protection against corrosion in the environment of high-temperature engine oil as compared with the materials A and B according to the conventional technique is recognized. However, the material is a general bronze material and an excellent effect on abrasion resistance which will be described hereinlater cannot be expected. Particularly, it was recognized that rapid bearing abrasion occurs in slightly bad environment such as sudden acceleration/deceleration or contamination in the engine oil supplied from the internal combustion engine.

[0081] FIG. 15 is an external view photograph which is a plan view of a new material block made of the material D as a candidate of the bearing for a turbocharger before immersion in high-temperature oil. In the diagram as well, there are portions seen black due to shading of gloss. However, in reality, the whole bearings are shining with a gloss peculiar to a brass alloy. FIG. 16 is an external view photograph which is a plan view of a material block made of the material D after immersion in oil of 180°C for 48 hours. In this case as well, in a

manner similar to the material C, in evaluation after immersion, no black corrosion product is generated and an effect of large improvement in protection against corrosion is produced. However, an excellent effect on abrasion resistance cannot be expected.

[0082] FIG. 17 is an external view photograph which is a plan view of new radial bearings 10 of FIG. 1 made of the material E before immersion in high-temperature oil. Although the radial bearings 10 of FIG. 17 are partly seen black due to shading of gloss, in reality, the whole bearings are shining with a gloss peculiar to a brass alloy.

[0083] FIG. 18 is an external view photograph of the radial bearings (made of the material E) of FIG. 17 after immersion in oil of 250°C for 48 hours.

[0084] FIG. 19 is an external perspective view photograph of a radial bearing used in FIG. 1 but made of the material F after immersion in oil of 250°C for 48 hours. In the diagram as well, although the radial bearing is partly seen black due to shading of gloss, in reality, the whole bearing is shining with a gloss peculiar to a brass alloy.

[0085] In the test of the materials E and F, the temperature of immersion oil was increased to 250°C, no black corrosion product was generated. That is, in the structure of the bearing for a turbocharger according to the invention, with respect to protection against corrosion in the high-temperature engine oil environment, in a manner similar to the materials C and D as general brass

materials, an effect of large improvement as compared with the conventional materials A and B was produced. To the effect of protection against corrosion, the elements of Cu and Zn largely contribute.

[0086] Changes in weight before and after the immersion evaluation of the materials will be compared. Since the initial weights of the samples are different from each other, as shown in FIG. 7, the ratios each obtained by dividing a weight change after the immersion evaluation by the initial weight are used for comparison by setting the change in the material F to 1.0 (reference).

[0087] Also in comparison of the weight changes after the high-temperature oil immersion, as compared with the conventional materials A and B, larger improvements in the materials C and D as general brass materials and the materials E and F as the embodiment of the invention were recognized. Particularly, in comparison between the material E of the embodiment of the invention and the conventional material A and in comparison between the material F of the embodiment of the invention and the conventional material B, improvements about 1/46 and 1/1065 were achieved.

[0088] As described above, in relative comparison regarding protection against corrosion, it was found the materials have excellent properties in accordance with the order of (materials C, D, E, and F), material A, and material B from the most excellent one.

[0089] FIG. 4 shows cross-sectional structures in the radial and axial directions of the copper alloy materials (bearings for turbocharger) 10 and 11 containing Cu, Zn, Al, Mn, and Si as main components as the embodiment of the invention.

[0090] As shown in FIG. 4, in the bearings 10 and 11, a very small Mn-Si (manganese silicide) compound 20 is crystallized out in a Cu-Zn alloy, that is, the base structure of the brass alloy. By preliminarily performing a process of drawing out of brass by pulling-out, rolling, or the like before the bearing is molded, the Mn-Si alloy 20 is elongated in the axial direction (pull-out and rolling direction) of the alloy material as conspicuously seen in the cross-sectional structure in the axial direction in FIG. 4. Al functions as a link of Mn-Si. The Mn-Si compound 20 and Al contribute to abrasion resistance.

[0091] Abrasion resistance required for the material of a bearing for a turbocharger will now be described. The abrasion resistance is an important property like the protection against corrosion in the high-temperature oil.

[0092] FIG. 8 shows results of evaluation on abrasion obtained by relative comparison of samples having the same shape (under the same conditions of load and time for evaluation). As speeds for evaluation, two kinds of speeds which are relatively low and high speeds are shown. With respect to the abrasion amount, comparison is made with an abrasion amount  $\mu\text{m}/\text{m}$  per unit sliding distance.

[0093] When the abrasion amount of the material F as the embodiment of the invention was set to 1.0 (reference), and the abrasion amounts of the above-described six kinds of materials were relatively compared with each other, it was found that the abrasion resistance of the materials is excellent with respect to the order of materials F, E, A, B, C, and D from the most excellent one.

[0094] The abrasion amount of each of the materials E and F of the bearing for a supercharger according to the embodiment is 1/10 or less of the abrasion amount of each of the materials C and B as general brass materials having more excellent protection against corrosion than the conventional materials A and B.

[0095] In the results of comparison of protection against corrosion in FIG. 7 and results of comparison of abrasion resistance of FIG. 8, signs were shown in the columns of judgment. "very good" is given to the materials which are judged as extremely good. The materials judged as "very good" are the materials E and F as the embodiment of the invention, by which a preferred bearing material can be supplied.

[0096] FIG. 6 shows a result of comparison of abrasion resistance paying attention to the directions of the Mn-Si alloy crystallized in the alloy with respect to the materials E and F as copper alloy materials having the most excellent abrasion resistance each containing Cu, Zn, Al, Mn, and Si as main components.

[0097] As a result of the abrasion resistance test, it was found that the direction of the Mn-Si compound 20 crystallized in the alloy with respect to the

sliding direction of the bearing material exerts an large influence on the abrasion resistance of the bearing material. FIG. 4 shows an example of comparison of abrasion resistance in the case of giving the following to the bearing: (1) sliding perpendicular to the diameter direction of the Mn-Sn compound 20, (2) sliding parallel to the longitudinal direction of the compound 20, and (3) sliding perpendicular to the longitudinal direction of the compound 20. The abrasion resistance test is an example of evaluation performed by using carbon steels S45C for machine structural use as a counter material of the bearing material under conditions of sliding speed of 0.2m/sec, pressed face pressure of 49 MPa, and use of turbine oil lubricating.

[0098] The case of sliding perpendicular to the longitudinal direction of the Mn-Si compound 20 (the case of (3)) shows the most excellent abrasion resistance. When the abrasion amount of the bearing material is set to 1.0 (reference), the abrasion amount in the case of sliding parallel to the longitudinal direction of the Mn-Si compound 20 (the case of (2)) and that in the case of sliding perpendicular to the radial direction of the Mn-Si compound 20 is 4.5 to 6.8 times for the following reason. In the cases of (1) and (2), as compared with the case of (3), the ratio of occurrence of fallout of the Mn-Si compound 20 itself is higher. Since the Mn-Si compound 20 has a hard phase, due to the fallen piece, an abrasive action is generated.

[0099] Since the fallout of the Mn-Si compound 20 causes increase in abrasion of the counter material and deteriorates the performance of the mechanical structure, it is important to match the sliding direction of the bearing material with the direction of the Mn-Si compound 20 in the best combination. By strengthening the base material of the alloy (for example, by adding Al), fallout of the Mn-Si compound 20 can be suppressed. It produces an effect at holding the hard phase and improving withstand load.

[00100] Consequently, the copper alloy materials having excellent characteristics of both protection against corrosion and abrasion resistance are the materials E and F. As long as a brass alloy contains 54 to 64 wt% of Cu, 0.2 to 3.0 wt% of Si, 0.2 to 7.0 wt% of Mn, 0.5 to 3.5 wt% of Al, and the rest of substantially Zn, improved protection against corrosion and abrasion resistance of the bearing for a turbocharger in an environment of high-temperature oil can be achieved.

[00101] Further, by making the elongating direction of the Mn-Si compound crystallized in the alloy match with required directions of the radial bearing and thrust bearing and employing the resultant material as the material of a bearing of a turbocharger for an internal combustion engine, the durability can be largely improved. The elongating direction of the Mn-Si compound is set to the axial direction of the rotation axis with respect to the radial bearing and the direction perpendicular to the rotary shaft with respect to the thrust bearing.



[00102] Although the example of using two radial bearings has been described in the embodiment, the invention is not limited to the number. For example, the invention can be applied to the case of using one radial bearing having a relatively long sleeve.

(Effects of the Invention)

[00103] According to the embodiment, in a turbocharger, a bearing structure having excellent abrasion resistance without generating a black corrosion product even in a high-temperature oil environment, for example, when an internal combustion engine is suddenly stopped can be provided, and a supercharger with high durability can be supplied.

[00104] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.